



EXECUTIVE SUMMARY

Water quality characteristics were determined in the Waimanalo watershed along the north and south fork of Waimanalo Stream, including the shoreline area on both sides of the stream mouth. Some stations also coincided with the UH(Laws) stations in the middle and upper reaches of the watershed. The sampling frequency was carried out at least once each month to characterize temporal trends and spatial variations in water quality. Water quality was assessed to determine compliance with the State Water Quality standards during wet and dry seasons. However, the lack appreciable rainfall throughout most of the year precluded a true characterization of wet conditions in the watershed. The low flow concentrations of constituents reflect a few occasions when measurable (1-2 inches), rainfall was recorded in the watershed. The term “low flow” used in this report refers to dry weather measurements rather than the conventional 7-day average low flow occurring once in 10 years.

Field tests included temperature, dissolved oxygen (DO), turbidity, conductivity and salinity. The chemical constituents included total suspended solids (“suspended solids”), chlorophyll-a, total dissolved nitrogen (“nitrogen”), dissolved nitrate-nitrite nitrogen (“nitrates”), dissolved ammonia nitrogen (ammonium nitrogen), and total dissolved phosphorus (“phosphates”).

The results of water quality analyses at Waimanalo Stream show relatively high levels of nitrogen that frequently exceed the State Water Quality Standards. Elevated levels are observed more often in the lower to middle reaches than in the upper reaches of the stream due to nonpoint sources, including plant cuttings, debris, trash and litter. Restricted stream flow and channel modifications are also key factors that contribute to impairment of water quality. The degradation of water quality appears highly magnified under low flow conditions, during which water samples were routinely analyzed. Nitrate concentrations were consistently high at Frankie’s Drive-In site, in contrast to the Waikupanaha site located farthest upstream. Nitrogen concentrations at Waikupanaha were



marginally in compliance with the State standards. However, nitrate concentrations at Frankie's Drive-In are higher than other stream monitoring sites by an order of magnitude. In spite of low rainfall in the upper reaches of the watershed, the low flow levels of nitrogen still show a seasonal trend. Generally, lower values are observed at most locations in the watershed during the dry period. On the other hand, nitrates and ammonium nitrogen were particularly higher between specific sampling sites, where stream segments appeared impacted by land-based activities or unknown sources of contamination. In-stream water quality data observed from the Mahailua sampling site, in particular, strongly suggested the origin of nitrogen from sources upstream. Also, the highest levels of turbidity and suspended solids were observed at the Mahailua location.

Phosphate levels in the watershed are in full compliance with the applicable State Water Quality Standards, and all sampling sites showed no discernible trend throughout the project period. In-stream oxygen levels are often depressed during the warm summer period. Dissolved oxygen levels fell below the 80 percent saturation (standard) level, around April through October which is considered the dry period of the year. The difference between wet and dry periods of dissolved oxygen is clearly shown at the Saddle City bridge site. Among key factors causing oxygen depletion in the watershed include elevated temperatures, restricted flow rates, low rainfall and decomposition of organic matter. The stream oxygen standard is met only 25 percent of time at the Mahailua site.



BACKGROUND

Waimanalo Stream has been selected as a water quality-limited segment under Section 303(d) of the Clean Water Act, identifying waters that are among the most polluted in the State. Water quality monitoring is given a high priority, and specific pollutants are identified as the cause of significant impairment to water quality. Adverse changes in water quality invariably occur during storm events having the potential to cause large runoff from nonpoint sources on land. The monitoring objective is to determine the relative contributions of pollutants associated with different land uses in the watershed and the impact to inland and coastal waters. The in-stream flow and concentration of constituents represent loadings generated by land-based sources in the watershed. The process of quantifying the total amount of loading is known as Total Maximum Daily Loads (TMDLs)¹. The watershed contribution of total suspended solids and nutrients is considered among the major pollutants that impair water quality in the receiving coastal waters.

The Waimanalo Watershed Project consists of several TMDL related investigations which include: (1) estimating pollutant loadings from storm runoff²; (2) correlating storm water concentrations of total suspended solids and turbidity; (3) developing a mathematical model for use in calculating numerical TMDLs; (4) GIS mapping of land use patterns; and (5) assessing the natural background (low flow) concentrations of water quality in the watershed.

Information and data from wet weather flows during storm events are essential in estimating pollutant loadings, establishing TMDLs, and implementing management strategies on source reduction measures. The storm water monitoring phase (simultaneous recording of flow and

¹ Waters in the State that do not meet the water quality standards must be identified under Section 303(d) of the Clean Water Act. TMDL is a method to allocate pollutant loads in receiving waters to which appropriate management actions are taken to improve water quality towards achieving compliance with the standards. The list of water bodies known as water quality limited segments approved by the EPA are available from the Department of Health's Environmental Planning Office.

² Loadings are estimated by combining stream flow volume and mean concentration of a pollutant, e.g., suspended solids, over a given period of time.



pollutant concentrations) and the TMDL model for this project are carried out by contractors for the Department of Health and the Environmental Protection Agency. The project objective is to develop a working model applicable to other watersheds with differing scenarios. Although not fully applicable in estimating pollutant loads, the quality of natural background water is helpful in assessing conditions between storm events. Water quality monitoring under normal, low flow conditions may reveal point sources. This knowledge is useful in applying site-specific mitigative controls and evaluation of long-term best management practices. The assessment of natural background concentrations of water quality is reported here.

WATER QUALITY

Sampling Stations

Water sampling stations were located along the north and south fork of Waimanalo Stream, including the shoreline area on both sides of the stream mouth. The following describes the station location, grid coordinates and noted comments for each site.

<u>I.D.</u>	<u>Station Location</u>	<u>Grid Coordinate</u>	<u>Remarks</u>
No. 04	Bellows North Runway	21° 21' 57.485" N 157° 42' 44.840" W.	Approximately 45.7m (50yds.) east of stream mouth.
No. 06	Bellows Life Guard Stand	21° 22' 08.704" N 157° 42' 45.152" W	Approximately 45.7m (50yds.) west of stream mouth.
No. 07	Bellows Runway Bridge	21° 21' 52.783" N 157° 43' 06.539" W	Approximately 0.8m (0.5mi.) above stream mouth.
No. 08	Saddle City Bridge	21° 21' 21.897" N 157° 43' 36.390" W	Near Saddle City road; vacant land area.
No. 09	Frankie's Drive-In	21° 21' 05.041" N 157° 43' 32.749" W	Bridge on Kalaniana'ole Hwy. Agricultural and residential area. Same as UH(Laws #16).
No. 11	Mahailua Bridge	21° 20' 46.225" N 157° 44' 00.000" W	Mahailua St. between Kumuhau and Kakaina Streets; small farms and nursery plant business. Same as UH(Laws #18).
No. 12	Waikupanaha	21° 20' 28.572" N 157° 44' 21.436" W	On Waikupanaha St. between Mahailua and Kakaina Sts. Same as UH(Laws #23).



No. 13	East Kumuhau	21° 20' 45.509" N 157° 44' 32.975" W	Corner of Waikupanaha and Kumuhau Sts; south fork tributary to Waimanalo Stream.
No. 14	West Kumuhau	21° 20' 44.989" N 157° 44' 31.952" W	Corner of Waikupanaha and Kumuhau Streets; North fork tributary to Waimanalo Stream.

(The Bellows lifeguard stand and the North end of the Bellows runway sites were included in sampling regime, since the Waimanalo watershed drains into the coastal waters of the bay. These sites are considered part of the Waimanalo Bay and both stations are in open coastal waters.)

Sample collection started in November 1998 at the following sites:

Station No. 04 - North Runway, Bellows Shoreline

Station No. 06 - Life Guard Stand, Bellows Shoreline

Station No. 07 - Runway Bridge, Bellows Field

Station No. 08 - Saddle City Bridge, Waimanalo

Station No. 09 - Frankie's Drive-in, Waimanalo

Additional stations were established to coincide with UH(Laws) stations the following month, expanding the coverage to the middle and upper reaches of the watershed.³ The additional sites included majority of the land-use in conservation district:

Station No. 11 - Mahailua Bridge, same as UH(Laws #18)

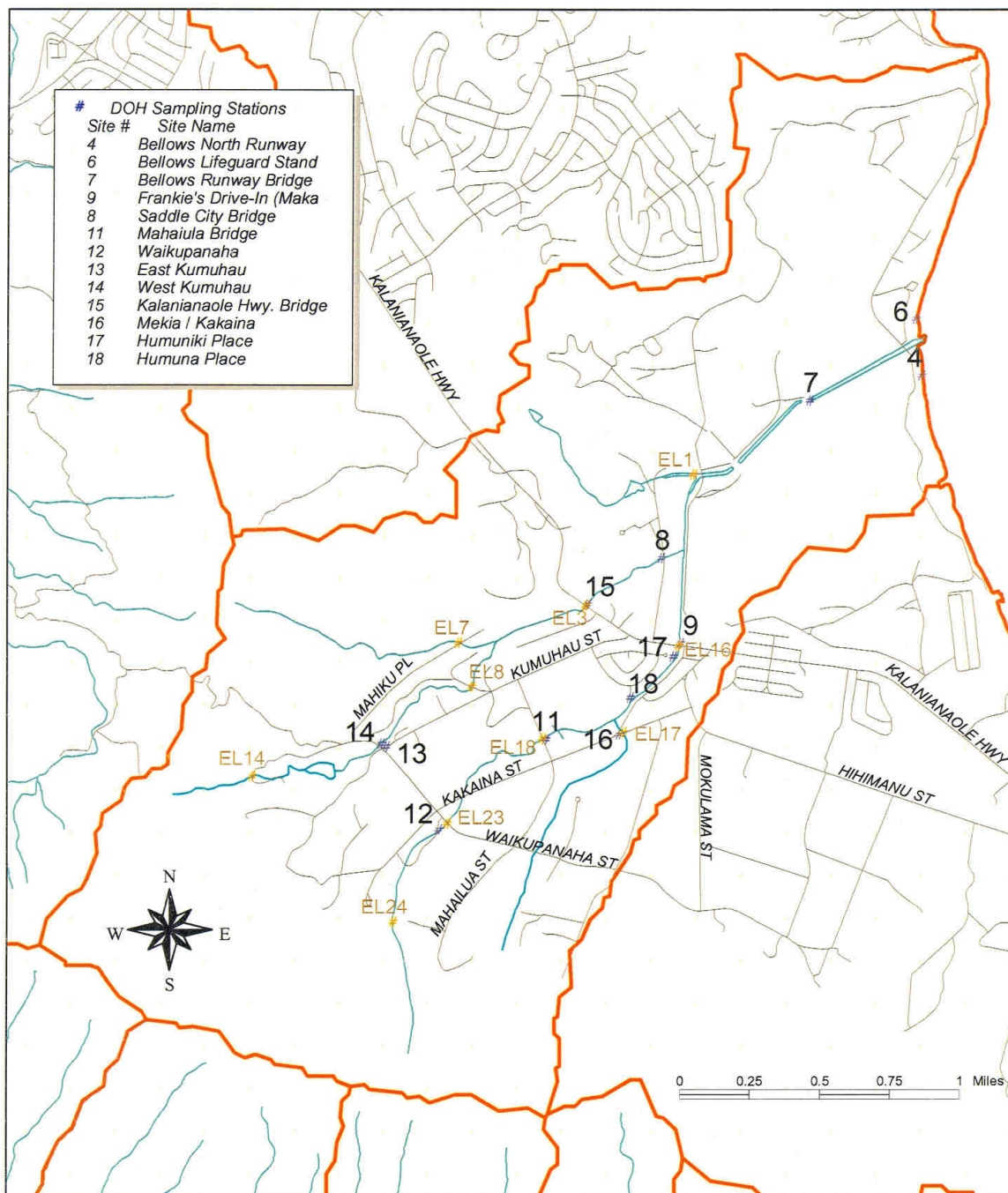
Station No. 12 - Waikupunaha, same as UH(Laws #23)

Station No. 13 - East Kumuhau, east fork, next to Stn. #14

Station No. 14 - West Kumuhau, below UH(Laws #14)

Station No. 15 - Kalaniana'ole Highway Bridge, same as UH(Laws #3)

³ For a description of land use patterns in the Waimanalo Stream watershed refer to the Department of Health report, *Land Use Patterns and Potential Polluted Runoff Sources in the Waimanalo Watershed, Koolaupoko District, Oahu, Hawaii*. Environmental Planning Office, September, 1998.



Waimanalo Watershed
DOH and Ed Laws' Sampling Stations

- # Ed Laws' Sampling Stations
- # DOH Sampling Stations
- Waimanalo Stream
- Watershed Boundary



The sampling was carried out twice each month for a year and once each month the following year, as consistency in the results allowed for monthly sampling without any appreciable changes to the data.

Additional exploratory sampling was also conducted to target a section of the stream above Station No. 09, Frankie's Drive-In. High nitrogen concentrations were consistently measured between Stations No. 09 and No.11, Mahailua Bridge.

Station No.16 - Nutrient "Hot Spot" area, same as UH(Laws #17)

Station No.17 - Nutrient "Hot Spot" area, above Frankie's Drive-In (#09)

Station No.18 - Nutrient "Hot Spot" area, above Station #17.

Field Tests and Laboratory Analyses:

Water quality parameters listed in the State Water Quality Standards⁴ were included in the list of tests. Field measurements included temperature, pH, DO, turbidity, conductivity and salinity. The nutrient analyses performed in the laboratory included suspended solids, chlorophyll-a, nitrates, ammonium nitrogen, and phosphate. Both field and laboratory protocols followed the methods and procedures outlined in the DOH/CWB Quality Management Plan⁵

Field tests were conducted using a YSI Model 85 Multi-parameter probe for pH, dissolved oxygen, conductivity, salinity, and temperature measurements. The instrument was calibrated using 50 uS/cm conductivity standard for seawater and 1 uS/cm conductivity standard for freshwater. Field turbidity measurements were conducted with a Hach Model 2100P turbidity meter.

⁴ Hawaii Administrative Rules, Title 11, Hawaii Department of Health, Chapter 54, Water Quality Standards.

⁵ Quality Management Plan for Surface Water Quality Monitoring, 1999.

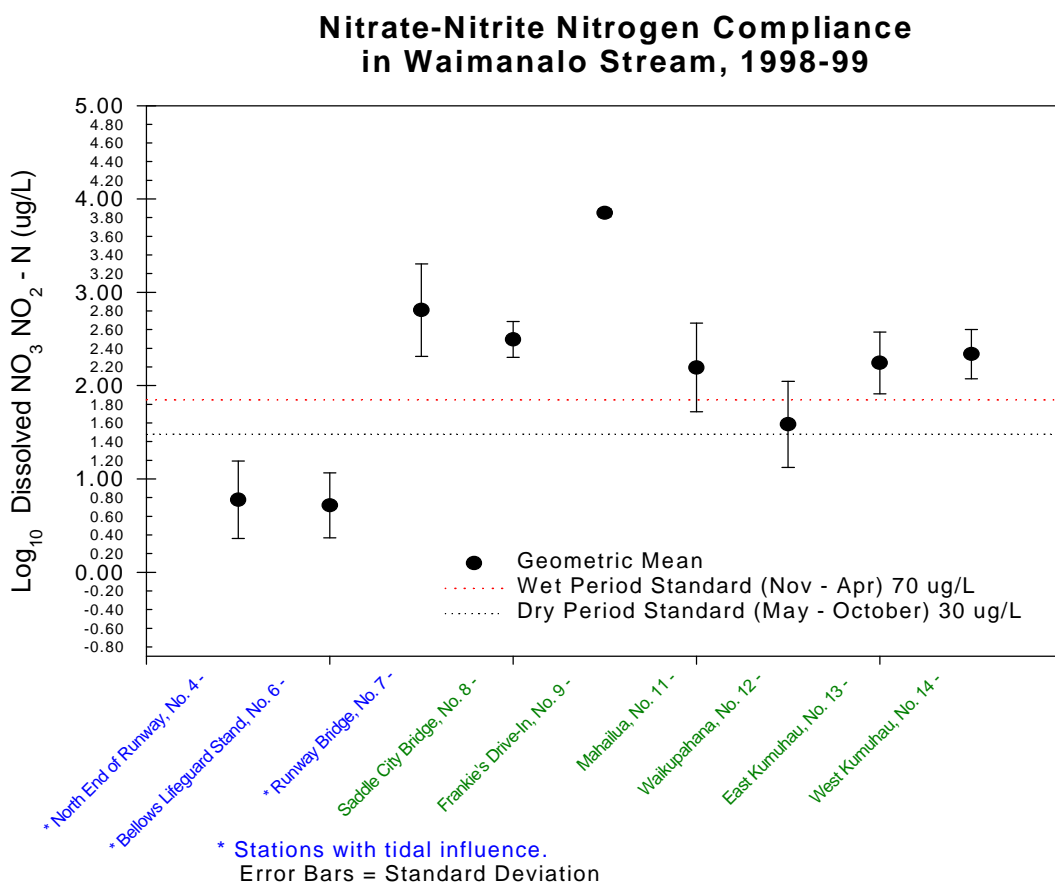


Sample Collection

Four samples from each station were collected in acid washed 1-liter hard plastic bottles, stored chilled in ice chests, and transported to the Department of Health laboratory on the same day.

Nitrates

The composite geometric mean values for nitrogen are plotted to show compliance or non-compliance with the wet and dry period standards. The results reveal that all of the fresh water stations in the watershed exhibit high nitrogen levels relative to the standards. The calculated geometric mean at Bellows shoreline (Open Coastal waters) shows compliance during the wet period only.

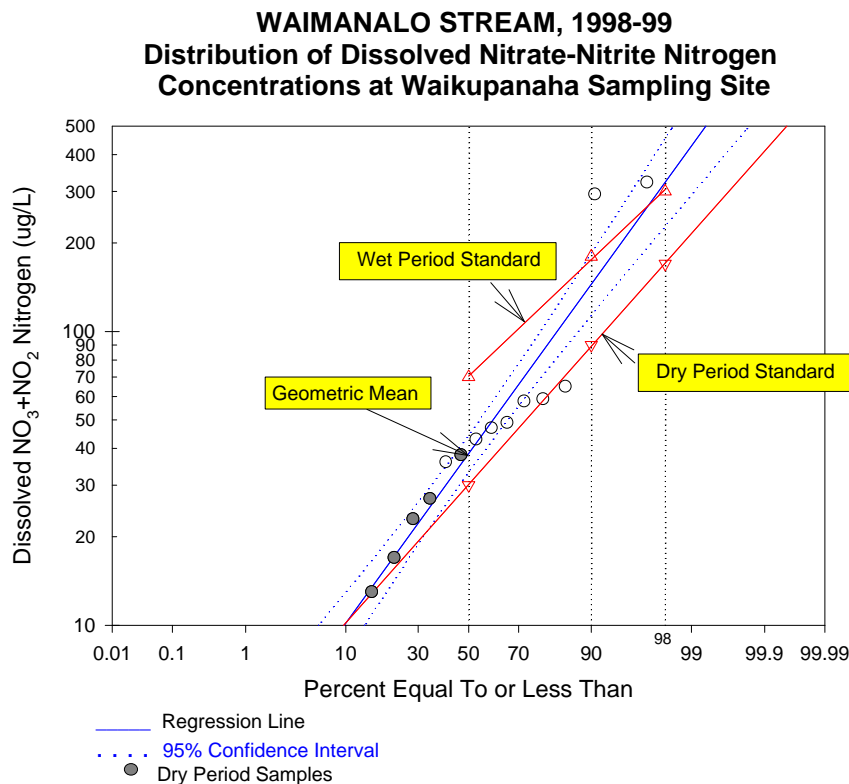




However, from Station No. 07 (Bellows Runway Bridge) in the brackish water and beyond Station No. 08 (Saddle City Bridge), nearly all of the stations located in Waimanalo Stream exceed the water quality standards. The only exception to this occur at the Waikupanaha site. Based on the probability plot on nitrogen values, water quality violation is rather marginal at the geometric mean standard. The Waikupanaha site is the farthest DOH upstream station (same as UH/Laws #23). The dry period standard was exceeded on two occasions only. For the most part of the project, nitrogen at Waikupanaha was in compliance during the wet period as well.

The distribution of nitrate levels at Waikupanaha sampling site is shown on the plot. The regression line (blue) is slightly above the standard at the geometric mean level. All samples taken during the dry period exceed the applicable standards. There were only two occasions when nitrate values exceeded the wet period standards.





The upper watershed appears to show a greater variability in water quality during the wet period, although rainfall was very minimal throughout the project year. The pattern may be associated with rainfall, runoff or a combination of increased ground water seepage during the wet period. West Kumuhau in particular measured relatively high amounts of suspended solids in March, January and April. Rainfall records at Waimanalo Experiment Farm show a total of 6.10 inches or a daily average around 0.2 inches during the month of January. The only appreciable amount of rainfall occurred in January at 1.05 and 1.73 inches during a 24-hour period. Station No. 09 (Frankie's Drive-In) recorded the highest nitrate levels with a very narrow range of variability as compared with the rest of the stations in the watershed. The nitrate values are lower by an order of magnitude at Stations No. 11 and No. 12 (Mahailua and Waikupanaha) than they are at Station No. 09 (Frankie's Drive-In).



Additional samples were collected between the upstream stations from Frankie's Drive-In and to the east and west fork (Stations No. 11 and 16, respectively (see map of sampling sites). The upstream results at Stations No. 17 and 18 continued to show high values of nitrates (5,530 and 3,560 ug/L, respectively). A survey of the area located potential sources in the Mahailua and Kakaina Street area. The activities such as plant nurseries, tropical fish raising, auto body and fender repair shop are situated near the stream.

Special Upstream Samples (2/22/00)	Nitrates (ug/L)	Ammonium Nitrogen (ug/L)	Total Nitrogen (ug/L)
Station. No. 09, Frankie's Drive-In	5080	141	5470
Station No. 17, upstream of No. 09	5530	5.0	5820
Station No. 18, upstream of No. 17	3560	13	3830
Station No. 16, upstream of No. 18 at Kakaina Street	164	18	1940
Station No. 11, Mahailua, upstream of No. 18	19	236	742

The high nitrate concentrations observed in the stream between Kalaniana'ole Highway (Frankie's Drive-In) and Mahailua Street suggest the discharge of a number of possible sources, among which include sewage, fertilizer and domestic animals, e.g., dogs, ducks, cats, cows, etc. Note: Ammonium concentration at Mahailua was exceptionally high, as shown in the above table. (Also see page 14, section on *Ammonia-N*.)

Indicator Bacteria

Since ammonium nitrogen may be implicated with sewage contamination as shown by the results, subsequent water samples were assayed for indicator bacteria, as well. The additional tests were carried out to determine the density of bacteria and the extent of contamination in Waimanalo Stream. The indicator bacteria results for the Runway Bridge in Bellows, Frankie's Drive-In, and Mahailua are shown on page 28. *Clostridium perfringens*, fecal coliform and enterococcus



were used as the indicator organisms in the tests. In all cases, the geometric mean values at Frankie's Drive-In recorded the highest density of indicator bacteria. The density of *C. perfringens* was between 440 CFU and 3,800 CFU, whereas upstream at Mahailua ranged between 10.8 CFU and 39.4 CFU. The geometric mean density of enterococcus at Frankie's Drive-In was 52,000 CFU



as compared with 11,000 CFU at Mahailua. Fecal coliform standard is still in effect for Hawaii, although the adoption of the EPA criteria is recommended⁶. The current standards for inland recreational waters states that fecal shall not exceed 200 CFU in 10 or more samples during a 30-day period. However, in conformance with the recommended EPA criteria, enterococci are

⁶ *Ambient Water Quality Criteria for Bacteria* - 1986, U.S. Environmental Protection Agency publication EPA440/55-84-002, January 1986.



routinely assayed, in addition to *C. perfringens*⁷. Fujioka recommends the use of *C. perfringens* in Hawaii based on the findings that traditional indicators, e.g., fecal coliform and enterococci, are found in the environment as part of the microbial flora in the soil. However, sources of *C. perfringens* are also found in feces of animals such as cats, pigs, dogs and ducks, that are commonly seen along the stream above Frankie's Drive-In. Therefore, it is unknown whether the high indicator bacteria levels are associated with sources of human sewage contamination.

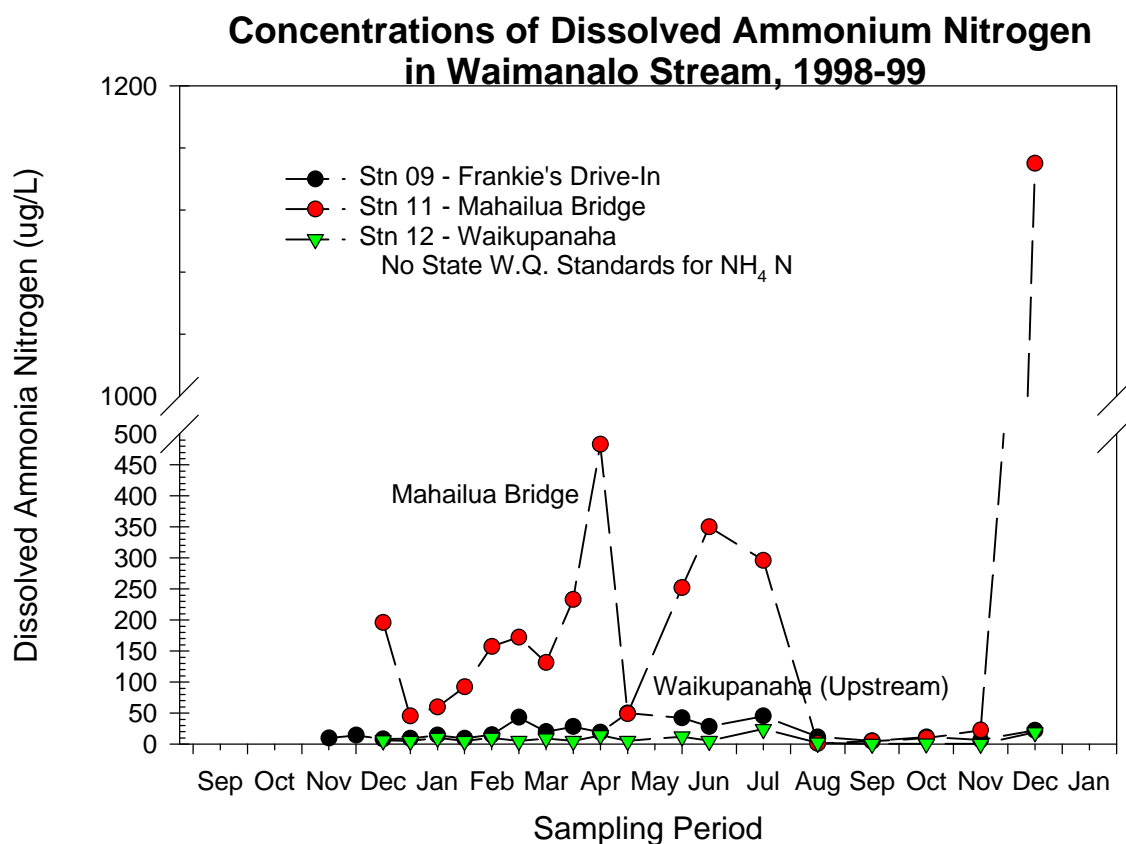


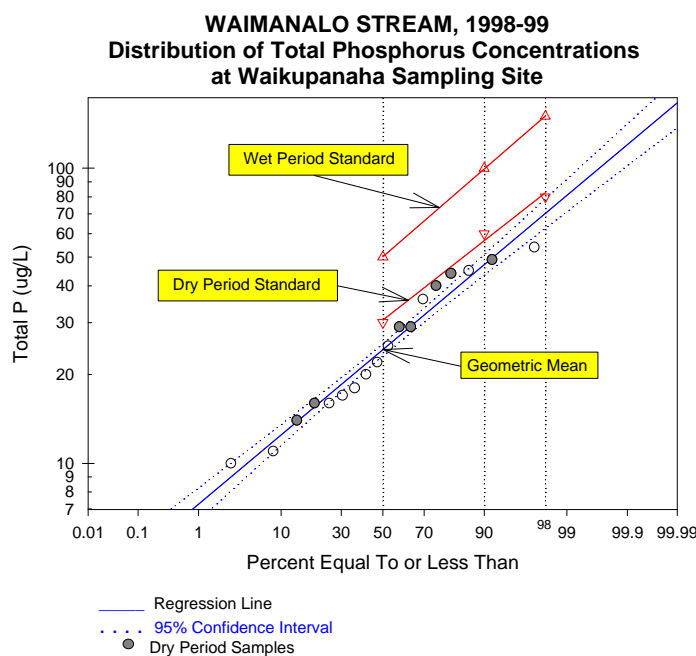
⁷ Fujioka, R., et al.. *Appropriate Recreational Water Quality Standards for Hawaii and Other Tropical Regions Based on Concentrations of Clostridium perfringens*. 1995.



Ammonium Nitrogen

There is no in-stream standards on ammonium nitrogen, however, the extent and magnitude of differences between certain locations are obvious. The range of values observed throughout the project year is shown on the chart. As with other constituents, the Mahailua Bridge site indicates the presence of very high ammonium nitrogen in the stream. The data strongly suggest unknown sources originating above Mahailua. The next upstream site is Waikupanaha where ammonium nitrogen is significantly lower.



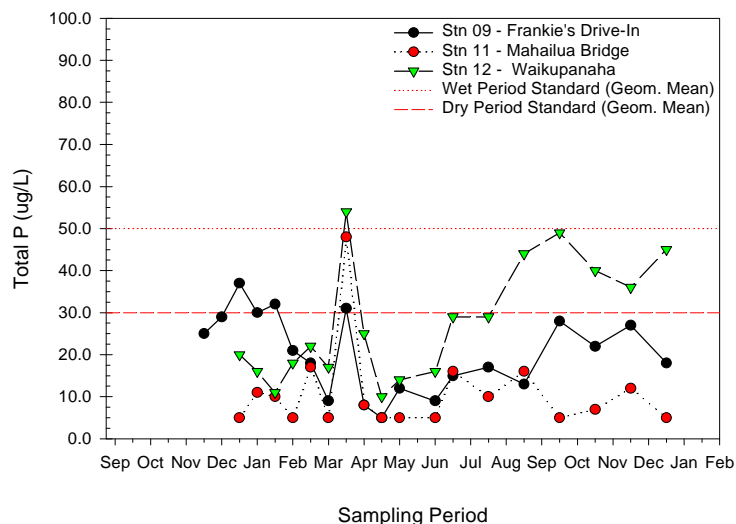


Phosphates

Phosphate levels are in compliance with the State Standards, as shown on the chart for the period 1998-99. The plot below shows a sudden spike in mid-March at all stations (Stations No. 08, 13, 14, not shown), except Bellows (Stations No. 04, 06, 07). The cause is not known. The levels at Waikupanaha appear to be elevated during part of the dry period, but show no distinction between wet and dry periods.

Although phosphate concentrations are generally higher at Waikupanaha, the annual mean concentration is not significantly different than levels at other sites. Phosphate controls in the watershed does not appear as critical as it is with the amount of nitrogen generated in the watershed.

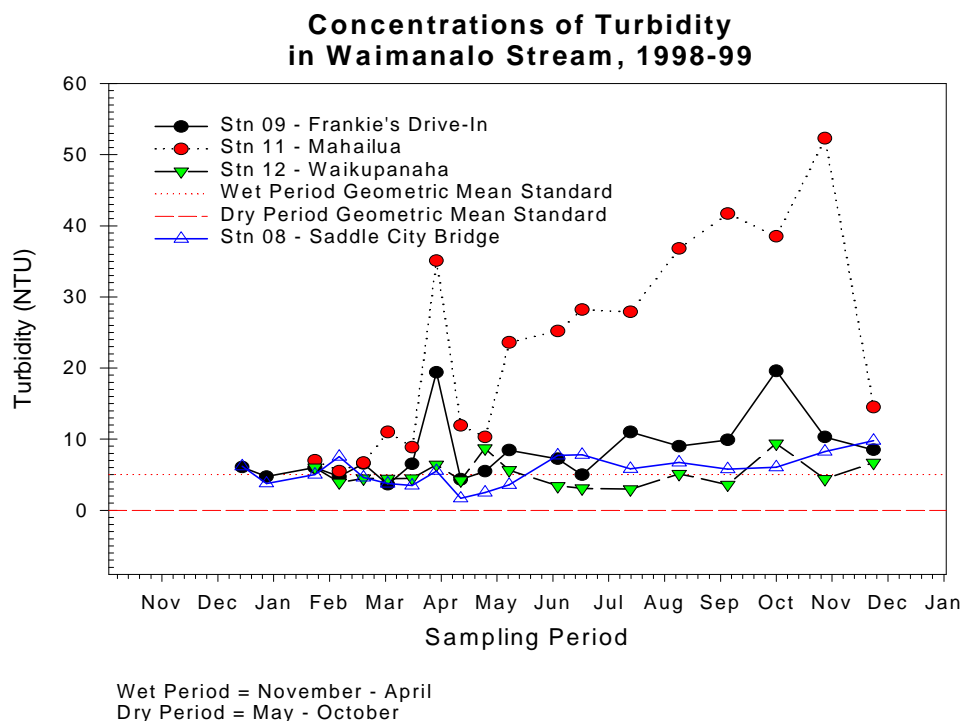
Concentrations of Total Phosphorus
in Waimanalo Stream, 1998-99





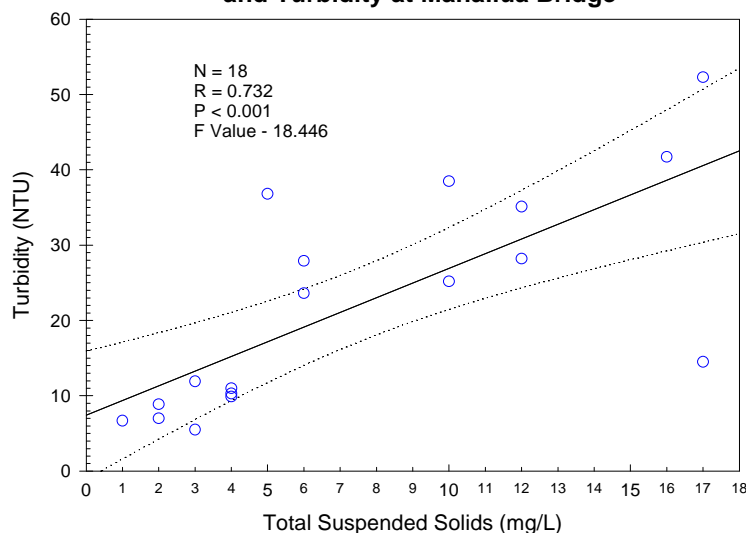
Turbidity

The standards for open coastal waters apply to waters at the Bellows lifeguard stand and the North end of the Bellows runway sites. These sites are included in sampling design since the Waimanalo watershed drains into the coastal waters of the bay. Runoff caused turbidity from the watershed directly impacts the coastal waters in Waimanalo bay. The standards for turbidity are exceeded throughout the year in Waimanalo Stream with the worst condition occurring at Mahailua. The Mahailua site recorded the highest turbidity, as compared with levels at Saddle City Bridge and Waikupanaha sites which exceeded the dry period standards only. However, turbidity levels exceeded the geometric mean standard at Saddle City Bridge during both wet and dry periods, whereas the levels at Waikupanaha were in violation only during the dry period. The observations of turbidity at the Mahailua site appear to be a chronic condition with a marked increase occurring through out the dry period beginning the month of May. The decline continued through the month of January through March 2000, although not shown on the chart.





**Relationship Between Total Suspended Solids
and Turbidity at Mahailua Bridge**



Suspended Solids

Low flow concentrations of suspended solids in Waimanalo Stream are generally within compliance of the standards with the exception of Frankie's Drive-In. Suspended solids exceeded the standard more often during the dry period than the wet period. In absence of any significant rainfall during the period, the data at Mahailua bridge appear to suggest upstream discharge from land-based sources. Moreover, this same location

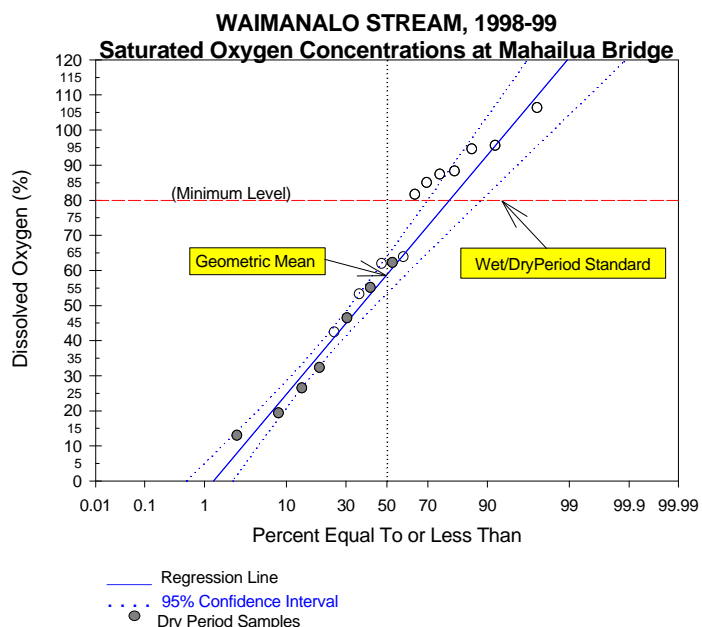
is where high levels of ammonium nitrogen are observed. The relationship between turbidity and TSS at Mahailua site is shown, which may further suggest suspended solids resulting from land-based activities. Obviously, the anomalous results at Mahailua are not considered normal background conditions.





Dissolved Oxygen

Dissolved oxygen levels are considerably lower during the dry period. The in-stream State standards for dissolved oxygen require no less than 80 percent saturation. Field measurements, usually taken during the mid-mornings, show a rapid decline during the warmer season from April through October when most of stations were below 80 percent saturation. Restricted stream flow and decomposition of plant material are more extensive during the dry summer months, causing additional depletion of oxygen. Oxygen levels were not determined during the night, when levels are expected to be considerably depleted due to plant respiration. Based on the probability chart, dissolved oxygen levels at the Mahailua site meet the standards approximately 25 percent of the time.





WAIMANALO WATERSHED, 1998-99

Water Chemistry Data

Bellocs # 04

Date	Time	Temp (C)	Salinity (PPT)	DO (mg/L)	Turbidity (NTU)	Nitrate (ug/L)	Total N (ug/L)	Total P (ug/L)	TSS (mg/L)	Ammonia (ug/L)	Chl-a (ug/L)	%Sat	S/Cond (uS)
11/24/98	0930	24.7	34.6		9.96	4	107	< 5	20	< 5	0.27		
12/7/98	0845	23.2	34.1		15.1	< 3.5	89	< 5	21	8	0.38		
12/22/98	0737	22.9	33.9	6.77		19	105	8	30	12	1.37	95.7	
1/4/99	0720	22.9	34	7.25	5	3.5	192	11	24	5	1.56	101.2	
1/19/99	0745	23.7	33.5	6.67	6.18	84	168	7	50	12	1.14	96.8	51
2/1/99	0714	22.5	34.9	6.42	10.3	4	115	5	25	8	0.3	90.4	53
2/16/99	0748	23.7	34.7	7.27	6.61	7	80	5	18	5	0.65	105.1	51.5
3/1/99	0758	24.6	34.5	7.21	3.1	4	78	< 5	< 37	< 5	0.97	104.2	52.7
3/16/99	0735	23	34.3	7.38	4.83	19	93	5	14	19	0.26	104	52.3
4/5/99	0800	23.3	34.7	7.7	7.83	4	168	< 5	13	< 5	0.42	98.9	52.8
4/19/99	0640	22.8	35.7	3.21	5.43	4	101	9	22	< 5	0.4	43.8	51.6
5/3/99	0729	26	34	5.08	4.29	13	98	6	14	15	1.13	75.8	52.2
06/01/99	0645	24.7	35.4	4.12	5.06	10	87	< 5	41	< 5	0.29	60.2	51.2
06/14/99	0700	26.2	35.2	5.69	4.98	< 3.5	80	< 5	14	16	0.46	85.5	53.5
07/19/99	0640	25.4	34.9	5.91	3.17	< 3.5	66	< 5	10	< 5	0.32	87.6	53.0
08/16/99	0725	25.9	35.1	6.66	5.47	3.7	81	< 5	14	8	1.07	100.1	53.3
09/20/99	0737	26.1	34.5	4.95	2.61	4	78	< 5	13	17	0.42	73.6	52.7
10/18/99	0745	26.7	35.1	5.43	2.95	1	85	6	12	14	0.41	82.4	53.3
11/15/99	0715	23.4	35.3	7.30	3.53	< 3.5	68	5	12	9	0.20	104.9	51.5
12/20/99	0635	23.4	35.1	9.4	3.9	< 10	78	6	397	9	0.6	120.80	52.3
	11800	0720	21.2	32.7	6.53	4.8	81	8	4	25	0.32	87.9	49.83
2/15/00	0717	24.6	34.6	6.17	4.8	59	168	5	81	9	1.53	90.2	52.5



The Waimanalo Watershed Monitoring Water Quality Project - 1998-1999

Bellocs #06

Date	Time	Temp (C)	Salinity (PPT)	DO (mg/L)	Turbidity (NTU)	Nitrate (ug/L)	Total N (ug/L)	Total P (ug/L)	TSS (mg/L)	Ammonia (ug/L)	Chl-a (ug/L)	%Sat	S/Cond (uS)
11/24/98	0955	24.1	34.4		8.8	5	120	< 5	10	13	0.24		
12/7/98	0908	23.3	33.6		22.2	< 3.5	89	7	14	6	0.37		
12/22/98	0754	23.1	34	8.16		20	99	8	30	10	1.17	95.9	
1/4/99	0745	23.2	34.6	7.12	11	3.5	99	< 5	27	< 5	1.33	101.6	
1/19/99	0807	23.8	35.3	6.93	11.4	24	130	< 5	42	17	0.5	100.1	52
2/1/99	0729	22.6	35.2	6.4	12.5	3.5	116	8	16	5	0.4	90.4	53.3
2/16/99	0805	23.9	35.1	6.84	9.04	3.5	62	5	12	5	0.54	99.1	53.2
3/1/99	0824	24.5	34.8	7.24	3.71	4	90	< 5	20	21	0.8	105.8	52.9
3/16/99	0755	23	34.3	7.38	4.83	19	93	< 5	14	19	0.026	104	52.3
4/5/99	0825	23.2	34.6	6.8	7.97	6	130	< 5	41	< 5	0.76	97.1	52.7
4/19/99	0659	23	35.6	3.56	4.78	< 3.5	92	< 5	16	< 5	0.26	40.4	51.9
5/3/99	0755	25.8	34.7	5.22	6.54	< 3.5	73	7	14	< 5	2.21	78.8	52.8
06/01/99	0700	24.8	35.2	4.02	6.98	13	73	< 5	35	< 5	1.05	59.9	53.3
06/14/99	0728	26.1	35.0	5.70	6.66	< 3.5	69	< 5	10	7	0.61	85.8	53.1
07/19/99	0737	25.4	35.1	5.92	6.08	< 3.5	64	< 5	14	< 5	0.37	88	53.5
08/16/99	0740	26.1	35.1	6.56	7.6	< 3.5	131	< 5	11	< 5	0.45	98.9	53.6
09/20/99	0759	26.0	35.1	5.07	4.2	3.5	82	< 5	11	15	0.36	76	53.3
10/18/99	0805	26.7	35.2	5.55	4.6	1	74	6	26	13	0.33	84.4	53.6
11/15/99	0740	23.4	35.2	7.36	4.17	3.5	65	5	8	9	0.22	105.8	51.6
12/20/99	0700	23.4	35.0	8.3	3.2	< 10	117	6	13	11	0.48	119.9	52.2
	11800	0740	21.2	34.4	6.48	< 1	60	7	11	9	0.27	89.9	52.1
2/15/00	0735	24.5	34.4	6.77	7.2	50	154	5	83	3	3.71	91.8	52.7



The Waimanalo Watershed Monitoring Water Quality Project - 1998-1999

Bellocs #07

Date	Time	Temp (C)	Salinity (PPT)	DO (mg/L)	Turbidity (NTU)	Nitrate (ug/L)	Total N (ug/L)	Total P (ug/L)	TSS (mg/L)	Ammonia (ug/L)	%Sat	S/Cond (uS)
11/24/98	1020	22.9	1.3		8.97	857	1188	22	4	6	3.34	
12/7/98	0933	22.5	9.4		3.29	469	664	17	4	7	7.77	
12/22/98	0817	22.3	0.6	7.19		761	825	13	15	< 5	12.2	83.9
1/4/99	0810	20.1	0.3	6.45	5		458	38	6	18	1.74	71.6
1/19/99	0828	22.8	3.3	5.26	6.16	1780	1720	36	9	69	2.04	62.8 6.4
2/1/99	0745	21.5	4.2	6.65	5.53		1770	28	2	36	4	77.2 7.58
2/16/99	0826	21.8	1.2	5.79	5.68		2080	24	2	17	3.75	66.6 232.6
3/1/99	0850	23.3	3.2	7.67	6.53	1580	1650	8	13	< 5	8.47	91.5 5.92
3/16/99	0820	22.6	1	6.98	7.27	1950	2260	28	3	88	5.35	81.6 200
4/5/99	0850	24.5	2	6.61	11.8	1530	1720	11	9	62	5.97	80.1 372.2
4/19/99	0710	23.1	0.6	3.35	12.9	1470	1638	13	8	29	8.41	43.5 1183
5/3/99	0820	26.6	2.6	5.39	7.24	1000	1090	13	7	< 5	13.2	68 382.1
06/01/99	0719	25.3	5.4	3.63	4.45	965	1140	8	11	16	5.20	47.0 9.62
06/14/99	0800	26.6	6.0	5.15	4.17	500	545	14	5	8	3.98	68.5 10.64
07/19/99	0805	25.9	3.1	4.80	3.96	257	458	14	3	289	4.49	60.1 5.83
08/16/99	0803	26.5	2.6	5.87	4.87	24	168	10	3	20	5.91	73.8 4773
09/20/99	0830	26.8	1.3	4.35	12.5	256	800	21	6	224	8.23	54.5 2560
10/18/99	0832	27.8	1.1	2.91	22	141	699	47	16	102	18.1	37.1 2222
11/15/99	0810	23	0.4	7.62	22.1	881	1260	20	12	26	14.3	88.5 803
12/20/99	0715	23.3	2.8	5.5	8.96	1550	2220	47	11	103	2.44	65.8 5.2
	11800	0800	19.8	0.5	6.36	1370	1570	24	4	< 1	2.11	80.4 1276
2/15/00	0800	23.5	1.5	5.68	7.6	878	2070	17	7	42	0.84	68.7 286.3



The Waimanalo Watershed Monitoring Water Quality Project - 1998-1999

Bellocs #08

Date	Time	Temp (C)	Salinity (PPT)	DO (mg/L)	Turbidity (NTU)	Nitrate (ug/L)	Total N (ug/L)	Total P (ug/L)	TSS (mg/L)	Ammonia (ug/L)	Chl-a (ug/L)	%Sat	S/Cond (uS)
11/24/98	1110	23.3	0.1		6.2	200	378	34	4	< 5	3.76		
12/7/98	1005	22.1	0.1		3.78	584	617	20	3	8	0.9		
12/22/98	1010	22.5	0.1	7.4		242	751	44	8	146	7.71	81.1	
1/4/99	1020	21.5	0.1	8.85	5		959	12	4	7	1.33	99.9	
1/19/99	1043	22.9	0.1	8.46	7.56	810	788	16	8	15	0.83	98.7	474.3
2/1/99	1025	21.6	0.1	7.84	4.63		741	22	1	9	0.97	88.9	431.6
2/16/99	0908	21.8	0.2	8.26	3.75		744	22	3	10	1.12	93.5	410.1
3/1/99	0937	21.1	0.1	10.4	3.49	482	610	10	2	< 5	0.63	117.4	398.8
3/16/99	0915	22	0.1	8.37	5.54	415	541	35	2	19	0.87	95.5	331.2
4/5/99	0947	22.4	0.2	6.59	1.68	254	788	7	1	6	0.61	72.5	375.9
4/19/99	0745	20.8	0.3	5.7	2.52	428	517	8	2	< 5	0.9	48.2	527
5/3/99	0910	24.5	0.2	6.23	3.59	224	358	6	2	9	1.62	74.2	387.2
06/01/99	0800	23.4	0.1	4.79	7.70	259	379	8	10	16	1.90	67.1	399.4
06/14/99	0904	24.2	0.1	6.45	7.82	289		10	14	38	1.48	70.0	409.2
07/19/99	0834	24.1	0.1	6.22	5.83	184	297	16	7	24	1.28	74.1	372.7
08/16/99	0857	25.2	0.2	6.65	6.73	276	399	18	6	< 5	0.99	80.1	383.2
09/20/99	0920	24	0.2	5.01	5.79	178	274	29	4	10	1.19	59.1	379.8
10/18/99	0921	23.3	0.1	6.1	6.07	213	392	21	6	< 5	0.52	70.7	409.3
11/15/99	0900	21.6	0.1	8.58	8.26	323	547	23	8	5	0.65	97.2	389.9
12/20/99	0750	21.5	0.2	7.8	9.8	478	758	36	14	11	0.93	107.0	394.1
	11800	0850	19.9	0.1	6.9	462	579	30	5	3	0.66	78.2	387.8
2/15/00	0840	21.2	0.1	6.69	6.6	419	820	18	6	9	0.67	75.3	439.5



The Waimanalo Watershed Monitoring Water Quality Project - 1998-1999

Bel lows #09

Date	Time	Temp (C)	Salinity (PPT)	DO (mg/L)	Turbidity (NTU)	Nitrate (ug/L)	Total N (ug/L)	Total P (ug/L)	TSS (mg/L)	Ammonia (ug/L)	Chl-a+R3 (ug/L)	%Sat	S/Cond (uS)
11/24/98	1045	24.1	0.1		6.08	7090	9380	25	7	10	2.88		
12/7/98	0946	23.8	0.2		4.74	7090	8390	29	7	14	1.92		
12/22/98	0839	23.6	0.1	9.22		6590	6220	37	34	8	212	108.7	
1/4/99	0835	22.3	0.2	10.74	6		7760	30	2	9	3.59	123.6	
1/19/99	0855	23.3	0.2	9.66	4.73	5400	4640	32	5	14	3.02	113.4	446.2
2/1/99	0817	22.8	0.1	9.55	6.57		5230	21	5	9	5.48	110.8	429.5
2/16/99	0850	23.8	0.2	12.2	3.65		5440	18	3	15	8.42	144.3	418.1
3/1/99	0919	23.1	0.1	12.3	6.51	6470	6460	9	14	43	13.4	143.5	401.2
3/16/99	0854	23.2	0.1	10.4	19.4	6240	6080	31	32	20	26.2	118.9	385.4
4/5/99	0921	24.4	0.2	9.4	4.34	7000	4640	8	21	28	35.7	112.9	392.1
4/19/99	0730	22.9	0.1	6.1	5.48	7300	6640	< 5	15	19	25.5	42.9	
5/3/99	0845	25.6	0.2	7.04	8.46	7650	7150	12	8	50	7.99	86.4	382.1
06/01/99	0740	24.1	0.2	6.24	7.24	7800	7710	9	11	42	9.02	72.3	392.5
06/14/99	0835	25.4	0.1	8.62	4.98	7170	5910	15	13	28	11.40	105.8	379
07/19/99	0925	25.6	0.1	8.56	11.0	7250	7070	17	18	45	13.2	104.9	378
08/16/99	0830	26.3	0.1	8.89	9.0	6880	6940	13	20	36	11.5	111	394.1
09/20/99	0855	26.1	0.2	7.21	9.9	7940	6520	28	14	27	5.1	88	374.6
10/18/99	0850	25.1	0.1	8.38	19.6	7460	8730	22	48	33	11.3	101.6	363.3
11/15/99	0830	23.3	0.1	8.61	10.3	7580	8070	27	18	36	6.47	103.5	433.6
12/20/99	0735	22.9	0.3	7.3	8.5	7810	8930	18	8	22	4.70	98.2	534
11800	0831	21.4	0.1	8.87	10.1	3620	4040	16	7	2	9.40	98.4	384.7
2/15/00	0824	23.0	0.1	8.81	5.3	3080	6350	6	9	13	10.4	103.1	463.8
2/22/00	0722	22.3	0.1	7.94	4.5	5080	5470	12	6	141	8.43	91.3	412.9



The Waimanalo Watershed Monitoring Water Quality Project - 1998-1999

Bellows #11

Date	Time	Temp (C)	Salinity (PPT)	DO (mg/L)	Turbidity (NTU)	Nitrate (ug/L)	Total N (ug/L)	Total P (ug/L)	TSS (mg/L)	Ammonia (ug/L)	Chl-a (ug/L)	%Sat	S/Cond (uS)
12/22/98	0900	21.9	0.1	7.14		112	471	< 5	2	196	0.08	81.7	
1/4/99	0900	21.5	0.2	8.26	7		578	11	2	45	0.12	95.6	
1/19/99	0920	22.1	0.3	8.23	5.5	406	244	10	3	60	0.12	94.6	520
2/1/99	0844	21.8	0.1	7.64	6.68		690	5	1	92	0.13	87.4	519
2/16/99	0927	21.9	0.2	7.44	11	305	547	17	4	157	0.37	85	510
3/1/99	1004	21.5	0.1	9.4	8.87	208	565	5	2	172	0.17	106.4	511
3/16/99	0953	21.9	0.1	7.72	35.1	328	622	48	12	131	0.96	88.3	461.3
4/5/99	0958	22.5	0.1	5.89	11.9	237	244	8	3	233	0.27	63.9	512
4/19/99	0800	21.5	0.1	3.67	10.3	237	694	< 5	4	483	0.18	42.5	439
5/3/99	0930	23.3	0.2	3.97	23.6	200	741	< 5	6	49	1.14	46.5	551
06/01/99	0835	23.2	0.1	4.44	25.2	296	670	< 5	10	252	0.07	62.2	524
06/14/99	0920	23.0	0.1	4.74	28.2	367	740	16	12	350	0.58	55.2	476.0
07/19/99	0903	23.6	0.1	2.74	27.9	294	636	10	6	296	0.45	32.4	498.0
08/16/99	0925	24.3	0.1	2.22	36.8	160	688	16	5	354	0.77	26.5	563.0
09/20/99	0948	24.5	0.2	1.63	41.7	97	428	< 5	16	304	4.25	19.4	560
10/18/99	0945	23.7	0.1	1.13	38.5	15	415	7	10	360	9.67	13	579
11/15/99	0925	22.5	0.1	4.62	52.3	9	710	12	17	354	22.2	53.3	580
12/20/99	0810	23.0	0.7	5.7	14.5	172	566	< 5	17	1150	0.09	62.0	1251.0
	11800	0910	20.7	0.1	6.62	9.9	145	25	4	58	0.22	73.9	362.6
	12500	0830	19.8	0.1	6.49	5.4	152	13	1	90	0.07	71.1	473.9
	20100	0715	21.6	0.1	6.06	7.5	131	11	2	134	0.05	68.6	463.5
	20700	0745	20.1	0.1	7.15	28.2	119	< 5	10	73	0.10	78.8	407.3
2/15/00	0901	21.6	0.1	5.93	12.2	74	456	< 5	4	159	0.09	67.1	443.1
2/22/00	0905	21.9	0.1	5.88	10.8	19	742	38	5	236	0.08	67.2	454.1
2/28/00	0724	22	0.1	5.58	16.6	12	942	31	12	330.000	0.11	63.9	474.2



The Waimanalo Watershed Monitoring Water Quality Project - 1998-1999

Bellocs #12

Date	Time	Temp (C)	Salinity (PPT)	DO (mg/L)	Turbidity (NTU)	Nitrate (ug/L)	Total N (ug/L)	Total P (ug/L)	TSS (mg/L)	Ammonia (ug/L)	Chl-a (ug/L)	%Sat	S/Cond (uS)
12/22/98	0923	21.9	0.1	8.2		65	161	20	4	6	0.18	91.4	
1/4/99	0920	21.7	0.1	8.37	6		339	16	12	< 5	0.37	95	
1/19/99	0947	22	0.1	8.27	3.93	294	379	11	3	< 10	0.44	94.5	504
2/1/99	0907	21.7	0.1	8.04	4.49		176	18	1	5	0.35	91.5	474.6
2/16/99	0958	21.4	0.2	8.41	4.43	322	108	22	3	10	0.97	99.1	450.9
3/1/99	1020	21.2	0.1	11.4	4.48	43	112	17	6	< 5	1.27	128.9	434.3
3/16/99	1015	21.3	0.1	8.41	6.42	59	171	54	7	9	1.67	95.1	393.6
4/5/99	1010	22.2	0.2	7.59	4.19	47	379	25	4	< 5	0.84	87	420.8
4/19/99	0825	21.2	0.2	5.7	8.7	49	115	10	8	14	1.87	48.2	309.9
5/3/99	0955	22.4	0.2	6.08	5.63	38	113	14	6	< 5	0.78	70.4	395.3
06/01/99	0900	23.1	0.1	5.06	3.41	8	980	16	6	12	0.66	68.1	371
06/14/99	0950	22.6	0.1	5.95	3.07	7	88	29	1	< 5	0.12	69.0	379.7
07/19/99	0940	23.1	0.1	6.18	2.95	23	131	29	3	24	1.32	72.1	379.1
08/16/99	0948	23.8	0.1	7.43	5.11	13	122	44	1	6	1.86	87.7	366.1
09/20/99	1020	23.5	0.1	6.08	3.6	17	133	49	2	< 5	0.25	71.1	356.4
10/18/99	1007	23.4	0.1	6.46	9.4	27	377	40	13	< 5	0.57	74.6	353.9
11/15/99	0945	21.4	0.1	12.84	4.4	36	176	36	14	5	0.14	144.5	229.1
12/20/99	0825	21.6	0.2	8.4	6.7	58	195	45	4	19	0.10	123.8	465.1
	11800	0928	21.1	6.81	9.0	114	171	45	6	75	0.29	77.9	286.4
2/15/00	0933	21.7	0.1	7.69	8.5	56	134	28	11	3	0.25	87.2	342.2



The Waimanalo Watershed Monitoring Water Quality Project - 1998-1999

Bellocs #13

Date	Time	Temp (C)	Salinity (PPT)	DO (mg/L)	Turbidity (NTU)	Nitrate (ug/L)	Total N (ug/L)	Total P (ug/L)	TSS (mg/L)	Ammonia (ug/L)	Chl-a (ug/L)	%Sat	S/Cond (uS)
12/22/98	0938	22.5	0.1	8.49		157	268	20	14	12	0.48	98.4	
1/4/99	0938	21.1	0.1	8.45	8		1141	7	12	17	0.31	94.6	
1/19/99	1005	22	0.1	8.6	7.56	487	518	8	3	20	0.59	98.7	427.1
2/1/99	0938	21.5	0.1	8.34	16.6	324	508	19	6	16	0.36	94	292.7
2/16/99	1015	21.2	0.1	9.4	12.6	318	339	28	8	20	2.12	105.6	281.3
3/1/99	1045	21.6	0.1	8.98	8.05	262	328	16	2	16	1.96	106.8	315.1
3/16/99	1030	21.3	0.1	7.88	68.9	591	739	45	34	133	1.7	88.9	277.3
4/5/99	1035	22.4	0.1	7.98	6.83	197	518	18	4	12	1.63	92.1	290.6
4/19/99	0840	21.7	0.1	5.7	7.4	178	325	8	3	19	1.54	47	2706
5/3/99	1015	23.4	0.2	6.3	6.87	171	270	15	2	23	1.93	74	278.2
06/01/99	0920	23	0.1	6.53	3.87	25	131	5	2	12	0.67	81.6	310
06/14/99	1015	23.3	0.1	8.03	7.06	164	350	13	6	25	1.85	94.1	282.1
07/19/99	1002	23.3	0.1	7.74	4.84	159	226	20	4	20	1.04	90.9	269
08/16/99	1010	23.9	0.1	8.86	12.20	63	150	19	4	22	1.2	104.9	261.5
09/20/99		23.4	0.1	6.80	7.62	93	266	43	4	20	0.6	80.0	269.6
10/18/99	1026	22.6	0.1	7.70	7.45	111	244	28	2	9	0.44	88.9	265.1
11/15/99	1000	21.7	0.1	7.62	7.98	143	311	27	4	5	0.75	92.4	280.2
12/20/99	0845	21.7	0.1	9.4	16.4	301	476	30	6	33	0.38	118.0	290
	11800	0941	20.5	0.1	7.13	156	261	22	2	18	0.86	79.1	343.7
2/15/00	0950	21.8	0.1	7.78	11.1	61	198	14	2	29	1.00	88.6	389.7



The Waimanalo Watershed Monitoring Water Quality Project - 1998-1999

Bellocs #14

Date	Time	Temp (C)	Salinity (PPT)	DO (mg/L)	Turbidity (NTU)	Nitrate (ug/L)	Total N (ug/L)	Total P (ug/L)	TSS (mg/L)	Ammonia (ug/L)	Ch-a (ug/L)	%Sat	S/Cond (uS)
12/22/98	0950	21.2	0.1	8.5		132	257	27	21	14	0.34	96	
1/4/99	1000	21.1	0.1	8.09	13		467	23	5	17	0.13	91.1	
1/19/99	1020	21.9	0.1	8.41	7.56	433	460	10	6	27	0.24	96.2	332.6
2/1/99	1000	21.7	0.1	9.23	7.67	340	393	17	5	28	0.67	105.1	371.8
2/16/99	1043	21.5	0.1	8.89	7.54		284	22	3	21	1.7	100.7	336.6
3/1/99	1100	21.7	0.1	8.66	10.8	389	517	19	5	38	0.35	98.7	274.9
3/16/99	1045	21.1	0.1	9.24	34.7	409	525	39	19	43	3.36	104.6	244.6
4/5/99	1045	22.6	0.1	7.44	8.88	339	460	13	4	17	0.81	86.1	269.4
4/19/99	0855	22.4	0.1	5.2	11.9	251	347	9	25	10	36.9	48.7	
5/3/99	1025	23.3	0.1	6.25	8.75	241	376	13	2	22	0.57	73.3	262.3
06/01/99	0930	23.1	0.1	6.67	4.10	237	323	14	4	15	3.21	83.4	312
06/14/99	1030	23.6	0.1	7.74	10.7	37	147	20	8	44	5.16	92.4	270.0
07/19/99	1034	23.5	0.1	6.90	9.04	269	273	26	5	24	0.40	81.2	257.8
8/16/99	1022	24	0.1	8.37	14.1	123	152	21	6	9	0.58	97.2	257.2
9/20/99		24	0.1	5.86	10.9	157	265	37	5	46	0.48	69.8	268.7
10/18/99	1053	23.2	0.1	7.22	9.43	157	326	30	2	28	0.29	83.2	266.5
11/15/99	1015	22.2	0.1	7.6	10.5	237	429	28	4	16	0.34	91.1	273.5
12/20/99	0900	21.6	0.2	9.3	7.4	229	394	28	5	30	1.02	120.1	361
	11800	0955	20.3	0.1	7.21	298	489	32	5	13	0.30	79.8	264.2
2/15/00	1000	21.7	0.1	7.50	14.0	236	644	24	5	23	0.31	85.6	316.



Waimanalo Watershed, 1998-99
Indicator Bacteria

#7 Runway Bridge (Brackish Water)	Enterococcus (CFU)	F. Coliform (CFU)	C. perfringens (CFU)	Salinity (PPT)
6/14/99	190	73.8	5.3	6
8/16/99	108	80	7.3	2.6
9/20/99	47.1	112	12.1	1.3
11/15/99	950	531	21.1	0.4
1/18/00	130	237	41.4	0.5
2/15/00	510	580	52.5	1.5
3/6/00	5.5	16.6	2.8	6.8
Log Mean	118.8	134.6	12.9	1.7
Max	950	580	52.5	6.8
Min	5.5	16.6	2.8	0.4
#9 Frankie's Drive In (Fresh Water)				
6/14/99	7700	4900	549	
8/16/99	16000	11700	1250	
9/20/99	52000	37000	774	
10/18/99	10400	20000	3800	
11/15/99	16000	560	3200	
1/18/00	7800	9600	990	
2/15/00	6700	5900	440	
3/6/00	4400	5320	510	
Log Mean	11798.9	7597.4	1147.1	
Max	52000	37000	3800	
Min	4400	560	440	
#11 Mahailua (Fresh Water)				
6/14/99	3400	1323	26.3	
8/16/99	11000	824	10.8	
9/20/99	7000	720	39.4	
10/18/99	144	250	31	
11/15/99	520	600	18.3	
1/18/00	500	1000	38	
2/15/00	560	570	14.1	
3/6/00	22.2	11.1	2.8	
Log Mean	621.6	343.4	39.4	
Max	11000	1323	39.4	
Min	144	250	10.8	

